IS THE ACCURACY OF PRECIPITATION MEASUREMENTS DEPENDENT UPON THE AREA OF THE RECEIVER OF THE GAGE? [1]

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[Meteorologische Zeitschrift, September, 1923.]

The extent to which the area of the receiver affects the accuracy of precipitation measurements has been studied in detail for German precipitation conditions by Hellmann.[2]

From these observations it developed especially that the amount of precipitation from gages with receiver areas of 500 to 1,000 cm.² would under similar conditions be measured with similar accuracy.

With respect to the construction of various rain-gages it should be especially noted that the ratio between wetted perimeter and the receiver areas is the same. The size of the aperture angle of the funnel is also of importance.

During the cold snow season the Hellmann observations also show no great differences between amounts of precipitation deposited in gages with receivers of different areas.

As it is of practical importance to use a smaller and lighter gage for an intensive concentration of groups of precipitation stations, comparative measurements were undertaken during the last year between the old Swedish rain gages of 1,000 cm.² receiver area and a smaller one of 200 ² cm., mainly of the Hellmann type, at several Swedish stations under very different climatic conditions. The question at issue was whether a smaller rain-gage is suitable for the varying conditions of Swedish precipitation.

Following I present a brief account of the results thus far obtained. Of the Swedish gage of 1,000 cm.² receiver area (for details of this see H. E. Hamburg, Les Pluies en Suède, 1860–1890, Appendix aux Observ. Meteor, Suedoises, vol. 52, 1910), the ratio V, between wetted perimeter and receiver area, is very suitable, $V=3.0$. In this respect the large gage is superior to the original Hellmann one in which $V=7.5$; otherwise, under similar conditions, a more satisfactory result should be expected from the large Swedish gage, especially in regard to smaller amounts of precipitation.

To diminish the loss through wetting in the smaller gage, I have employed a movable funnel, 15 cm. below the upper rim of the gage, during the warmer period of the year. The ratio, V, therefore becomes reduced to $V=5.0$. The measurement of the precipitation in the smaller gages is accomplished by the aid of cylindrical measuring glasses graduated to 0.1 mm. The direct error in measurement with either one or the other gage arising from inaccuracy of the selected receiver and the graduation of the proper measuring glass can not, as control measurements have shown, exceed 10 per cent.

In Table 1 are combined the monthly sums of precipitation by both gages at the two experiment stations, Lund ($\varphi=55°\ 37'$, $\lambda=13°\ 2'$ east of Greenwich), and Abisko ($\varphi=68°\ 21'$, $\lambda=22°\ 30'$ east of Greenwich). At Lund, the southerly station, there was only a small difference between the two gages, as at this station they were freely exposed without shielding device, as they usually were at the Swedish stations previously. (See H. E. Hamburg, l. c.) The comparative measurements at this station are therefore comparable with those of Hellman, and also with respect to the climatic relations. In conformity with the Hellmann results there is also a small excess for the smaller rain gage during the snow season. This appears plainly in Table 2.

[1] Translated from the German by H. C. Frankenfield.

[2] G. Hellmann, Observations of rain gages of different construction. (Abhandl. des Konigl. Preuss. Meteorol. Inst. 1. Bd. Nr. 3, Berlin, 1890.)

TABLE 1.—*Precipitation in millimeters*

	Lund, 1921			Abisko, 1921		
	Receiver area, cm.²			Receiver area, cm.²		
	1,000	200	Difference (per cent)	1,000	200	Difference (per cent)
	Without shield			With shield	Without shield	
January	83.4	86.2	+3.4	26.6	22.3	−16.0
February	21.0	21.9	+4.3	23.6	18.6	−20.9
March	21.5	21.3	−0.9	13.5	11.0	−18.6
April	24.4	25.2	+3.3	16.9	15.6	−7.7
May	19.5	19.4	−0.5	45.8	41.2	−10.0
June	64.3	62.1	−3.4	70.6	69.3	−1.9
July	42.5	42.5	0.0	52.5	50.9	−3.0
August	101.7	99.7	−2.0	111.3	107.6	−3.3
September	47.3	46.3	−2.1	23.2	21.9	−5.7
October	58.8	58.7	−0.2	41.8	42.1	+0.7
November	42.1	42.7	+1.4	13.1	12.4	−6.1
December	94.0	97.4	+3.6	11.3	10.8	−4.5
Year	620.5	623.4	+0.5	450.2	423.7	−5.9

	Lund, 1922			Abisko, 1922		
	Receiver area, cm.²			Receiver area, cm.²		
	1,000	200	Difference (per cent)	1,000	200	Difference (per cent)
	Without shield			With shield	Without shield	
January	33.3	34.2	+2.7	4.9	4.0	−18.0
February	23.4	24.0	+2.6	10.4	10.4	0.0
March	51.0	53.5	+5.0	4.6	4.8	+4.3
					With shield	
April	42.9	43.2	+0.7	9.4	9.6	+2.1
May	18.2	18.2	0.0	13.5	13.9	+3.0
June	62.9	61.0	−3.0	84.0	83.7	−0.4
July	92.5	87.4	−5.5	26.3	26.4	+0.4
August	77.1	73.9	−4.2	44.3	44.6	+0.7
September	87.7	84.2	−4.0	14.7	14.8	+0.7
October	26.6	25.0	−6.0	16.9	16.9	0.0
November	37.8	37.2	−1.6	35.1	36.4	+3.4
December	54.5	51.7	−5.1	13.4	15.1	+11.1
Year	607.9	593.5	−2.4	277.5	280.6	+1.1

TABLE 2.—*Precipitation in millimeters*

	Rain			Snow		
	Receiver area, cm.²			Receiver area, cm.²		
	1,000	200	Difference (per cent)	1,000	200	Difference (per cent)
Lund, 1921, January to December	521.6	519.5	−0.4	98.9	103.9	+5.1
Lund, 1922, January to December	523.3	507.5	−3.0	84.6	86.0	+1.6
Total	1,044.9	1,027.0	−1.7	183.5	189.9	+3.9

	Lervik (island of Jungfrun)		
	Receiver area, cm.²		
	1,000	200	Difference (per cent)
1920–June 30, 1923	25.8	26.5	+2.7
July, 1923	46.7	47.6	+1.9
August 1 to 20, 1923	22.7	23.4	+3.0
Total	95.2	97.5	+2.4

The fact that the smaller rain gage catches a little less rain during the summer months may be explained by the unsatisfactory ratio between wetting and the receiver areas. Nevertheless, it appears to be more probable that this difference is dependent upon the dissimilar exposure of the two gages. This is also indicated by a simultaneous series in the summer of 1920, one at Lervik (Table 2), by Herr Dr. E. de Rietz, during a botanical expedition to the Island of Jungfrun in Kalmarsund, the other by Herr R. Smedburg, first State hydrographer, on the west coast of Sweden.

The series of observations at Abisko show, on the contrary, great differences during the winter of 1921, in that the small gage caught a considerably smaller quantity of precipitation. With respect to this it may be remarked that the large gage from its original exposure was equipped with the shield mentioned heretofore, while the small gage was exposed freely. The effect of wind protection is significantly shown in the series of H. E. Hamburg [3] at Sarna, previously given. Table 3 gives a comparison of the same.

TABLE 3.—*Average precipitation in millimeters, Sarna, 1907–1910*

[According to comparative measurements with Swedish gages, with and without shields]

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Without shield	16.6	11.3	21.5	21.9	36.0	55.0	60.0	66.0	43.5	57.7	11.5	24.6	425.6
With shield	20.7	17.4	27.2	29.9	40.6	56.6	61.5	68.4	44.6	59.6	14.8	32.3	473.6
Difference (per cent)	−20	−35	−21	−27	−12	−3	−2	−4	−3	−3	−21	−24	−10

When these results are compared with the present series of observations at Abisko, it appears that the entire difference in the Abisko series of 1921 arises from the effects of the wind shield of the larger gage. The comparison of the smaller gage without shield with the larger one with shield affords under these hypotheses an insight into the effect of the wind movements.

Table 4 shows how the differences are apportioned to different wind velocities. During summer rains the difference is very small, and no variation with wind velocity is found The shield effect during the warmer portion of the year is therefore without moment. During snowfall the shield exerts such a decided influence that it becomes more effective with increasing wind force up to a certain critical force. Thereafter the effect of the shield appears to diminish rapidly. This may possibly be due to the stronger turbulence induced by the higher wind velocity which could not diminish the wind force to any extent.

TABLE 4.—*Abisko, 1921*

(Depth of precipitation in millimeters)

Wind velocity at height of 15 m.	Snow				Rain		
	Number of days	Receiver area, cm.²		Difference in per cent	Receiver area, cm.²		Difference in per cent
		1,000	200		1,000	200	
0 to 4 m. p. s.	26	36.2	34.2	−8	93.8	92.0	−2
5 to 9 m. p. s.	28	28.2	25.2	−10	134.2	130.2	−3
10 to 14 m. p. s.	21	52.4	42.4	−19	62.2	61.1	−2
Above 14 m. p. s.	19	43.3	38.2	−12			

[3] H. E. Hamburg. l. c. Page 13.

From March, 1922, the 200 cm² rain-gage at Abisko was equipped with a shield of the same reciprocal dimensional proportions as the larger one. Since that time the monthly sums, as well as those of the winter months (Table 1), show very similar values, much the same for one gage as for the other. The entire precipitation from April to December, 1922, differs only about 2 per cent, and even shows a higher result with the 200 cm.² gage.

That the same close agreement likewise prevails for snowfall if both gages are equipped with protecting shields, is evident from the comparison in Table 5. While the total difference for the snow fall before the installation of the shield on the smaller gage, was as much as −12 per cent, it here even passes over into a small positive value.

TABLE 5.—*Abisko*

Character of precipitation	Rain gage, receiver area, cm.²	Total precipitation in mm., 1921, to Mar., 1922	Rain gage, receiver area, cm.²	Total precipitation, Apr. to Dec., 1922
Rain	1,000 with shield	295.9	1,000 with shield	175.2
	200 without shield	289.2	200 with shield	175.3
	Difference (per cent)	−2.3	Difference (per cent)	0.0
Snow	1,000 with shield	174.2	1,000 with shield	82.4
	200 without shield	153.7	200 with shield	86.1
	Difference (per cent)	−12.1	Difference (per cent)	+4.5

From the comparative measurements, as above set forth, it may be concluded:

1. That the accuracy of measurement of the amount of precipitation with the smaller gage of 200 cm.² receiver area is equal to, or perhaps a little greater than, that of the old Swedish gage of 1,000 cm.² area.
2. That the smaller gage of 200 cm.² receiver area is well adapted to snow measurement.

The continuance of comparative observations, especially in Abisko, so far as regards measurements at a single station, a demonstration under extreme conditions to follow would serve still further to clarify the question.

At the request of the editor Mr. S. P. Fergusson, of the Instrument Division of the Weather Bureau, has supplied the following references to the literature on the development of the rain-gage:

There is a considerable literature on the subject of gages of different sizes, etc., and apparently the most complete investigations relating to this subject are:

(1) The comparisons of rain-gages of different dimensions and kinds at different heights, at Rotherham England, 1865–1900 and probably later. Results have been published at various times in British Rainfall, 1865, to date, particularly 1869, and in the Symons Meteorological Magazine. Summaries have been published by R. E. Horton, in "*The Measurement of Rainfall and Snow,*" in Jour. N. E. Water Works Ass'n, Vol. XXXIII, No. 1.

The gages employed varied in diameter from 25 to about 2,000 mm., the latter having an area of 0.001 acre.

(2) The investigations of Hellmann and others, mentioned in Lindholm's paper.

(3) Symons, G. J., "A contribution to the History of Rain Gages," in Quar. Jour. Roy. Met. Soc., 1891, probably contains numerous references up to that year.

All investigations apparently indicate that there is no appreciable difference in the "catch" of gages varying in diameter from 25 to 2,000 mm. the ratio of areas being 1 to 6,000.

It seems very probable that differences found by some observers are due to differences of construction. My own experience in New England and in the West with different kinds of gages, indicates that gages with shallow funnels have larger and more variable errors than do the deeper gages. The greater splashing of the larger drops occurring in summer may explain the deficiency in catch of the 200 cm.[2] gage used by Lindholm at this time of year. In mild climates such as that of England, wet snow adhering to the funnel would cause a more variable, and usually a smaller, catch on the part of the smaller gage.

The ratio V (p. 262) is that of the cylindrical portion of the gage to the area of the funnel (or bottom of the receiver).

PRESENT METHODS OF GLACIER STUDY IN THE SWISS ALPS

551.324(494)

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[Mount Rose Observatory, Reno, Nev., July 10, 1923

Contemporaneous with the later studies in glacier phenomena by Prof. P. Mercanton, of the University of Lausanne, an abstract of whose work appeared in Scientific American Supplement 85:194–5 (Mar. 30, 1918), is the investigation being conducted under the auspices of the Glacier Commission of the Physical Society of Zurich by Prof. A. de Quervain, of the Swiss Central Meteorological Office, assisted by Dr. A. Billwiller. Current reports are published in the Annalen der schweizerischen, meteorologischen Zentralanstalt and in briefer form in the Jahrbuch Ski.

In addition to the traditional measurements of glacier flow, the commission is endeavoring to determine the relation of the source of supply to the forward thrust and retraction of glaciers and to obtain so far as possible a view into the evolution of the glacier snow beneath the surface. The Clariden and Silvretta Glaciers were selected as the subject of study.

As a preliminary, snow stakes were erected at the mountain huts in the catch basin of the individual glaciers to determine the current growth and dimunition in the snow cover, and seasonal snow gages, known as Mougin Totalisators, were installed to determine the total annual precipitation. These consisted of an orifice flanked by a Nipher screen and terminating in a reservoir containing a saline solution in which the falling snow is melted and conserved. A laboratory test of the resulting dilution determines the amount of gathered precipiation. And iron tripod raises the totalizator above the reach of drifting snow.

Although the totalizator is the last word in simplicity, it probably lacks necessary precision, for the air currents in the exposed situations in which the gages are of necessity placed, must often be too strong to be controlled by the screen, and, furthermore, the cold may at times congeal the surface of the liquid content and seriously reduce the capacity of the reservoir by depriving it of its power to change the snow into water. Finally, frost plumes will readily form in cloudy weather upon the orifice and until slowly melted by the returning sun will prevent the entrance of snow. On the other hand, the contents may even be abnormally augmented by "snow smoke" from neighboring peaks unless the totalizator is so situated as to be beyond such influence.

The uncertainty that exists regarding the accuracy of the snowfall measurements is heightened by the fact that glaciers are situated in depressions, well called *glacial collectors, and are thus the natural recipients of* the drifting snow, providing they lie in the lee of the wind. Some glaciers, also, may be abnormal losers of snow, if they face the sun. Consequently, with similar snowfall but dissimilar exposure to the wind and sun, two adjoining glaciers may act quite differently. Furthermore, some basins, as Mercanton has pointed out, may by their topography so restrain glacial flow that excessive accumulation is necessary before forward thrust can occur.[1] Therefore, to determine the factor of accumulation, measurements were begun of the seasonal residue of snow upon the glaciers themselves.

Two points were selected, one at either end of the glacier, and were marked by a steel tube, known as a buoy, which was usually extended 5 to 6 meters each summer to rise above the new snow of the following winter. At first, the accumulation about these buoys was measured in terms of height, a method of considerable accuracy at any time in the season where the snow is wind-blown but particularly so at the close of the season of melting when the snow has attained practically its highest density through crystallization, as shown by the extremes of 49.0 to 61.5 per cent relative density obtained during the first 3 years.

However, to obtain dependable accuracy in connection with buoy measurements and also to obtain a view beneath the surface, a Mount Rose Sampler, *made in* short sections to facilitate packing up the mountain, was imported into Switzerland just as the Great War was breaking, and by the development of a special ice cutter[2] has been used to penetrate through two seasons' accumulation to the total depth of 5½ meters. To mark the division between the seasonal layers, a sheet of ochre of red or yellow to facilitate identification is spread around each buoy. The tendency of the ochre stain to spread does not militate against its use, for the movement is downward with the percolating water. Consequently, despite a maximum penetration by the ochre of 165 cm., the line between the two seasons' snows is sharply defined.

The immediate result of the measurements was the demonstration that the winter snowfall upon the glacier surface suffers considerably during the brief summer season, for although the water content of the season's snow cover at the end of the major snowfall as on June 17, 1917, was within the reasonable correlation of 20 to 25 per cent of the annual catch in the totalizator, the water content on August 8 was almost 100 per cent divergent. Consquently, the total annual precipitation bears far less relation to glacier growth than the actual residue of snow that remains as the composite result of winter snows and summer melting; although it is quite possible that a portion of the percolating waters may combine with the glacial snows below.

The second result, brought to light by the divergence between the accumulation indicated by the buoy and

[1] The analysis of these three factors of accumulation, dissipation, and topography would find *a harvest time of opportunity in* a season such as 1918–19. In this year of heavy snowfall, as noted by Mercanton, of 100 glaciers, 69 were growing, 4 were stationary, and 27 were diminishing. It will be of great interest to obtain the statistics for 1920–21, when the snowfall was light and the succeeding summer unusually warm. Of course, large glaciers, or rather glaciers with large collectors, should show less seasonal variation and might even continue to grow over one or even more deficient seasons. As Professor Mercanton remarks in this connection, "the large snow glaciers have without exception manifested a tendency to grow."

[2] Owing to the tendency of the ice to melt under pressure and friction of the cutter and then to refreeze immediately above it, leaving it imprisoned like a fish in ice, a set of teeth was cut on its bulbous upper side in order that by reversing the direction of rotation of the sampler, the cutter could recut its way to the surface.